

What I Claim Is:

1. An apparatus for generating a magnetic field, comprising:

a) a drilling means for drilling a borehole into the formation;

b) a means for carrying drilling fluid through the drilling means;

5 c) a measuring means, connected to the drilling means, for making nuclear magnetic resonance measurements while the borehole is being drilled, the measuring means comprising:

i) a means for producing a substantially axisymmetric static magnetic field through the drilling means and into the formation, the static magnetic field producing means comprising:

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a) an array of magnets surrounding the carrying means; and,

ii) a means for producing an oscillating field in the formation; and,

d) at least one magnetically permeable member located inside the drilling means for shaping the static magnetic field.

15 2. The apparatus of claim 1, wherein the array of magnets is annularly cylindrical.

3. The apparatus of claim 2, wherein the array of magnets comprises a plurality of segments, each segment is magnetized in a direction radially outward from and perpendicular to the longitudinal axis of the apparatus.

4. The apparatus of claim 3 wherein the magnetically permeable member in
20 combination with the static magnetic field producing means generates a long, uniform magnetic field in the axial direction.

5. The apparatus of claim 4 wherein the magnetically permeable member comprises a section of the carrying means.

6. The apparatus of claim 4 wherein the magnetically permeable member comprises a chassis surrounding a section of the carrying means.

7. The apparatus of claim 5 wherein the magnetically permeable member further comprises a chassis surrounding the section of the carrying means.

5 8. An apparatus for generating a magnetic field, comprising:

- a) a drilling means for drilling a borehole into a formation;
- b) a means for carrying drilling fluid through the drilling means;
- c) a measuring means, connected to the drilling means, for making nuclear magnetic resonance measurements while the borehole is being drilled, the measuring means comprising:

10 i) a means for producing a substantially axisymmetric static magnetic field through the drilling means and into the formation, the static magnetic field producing means comprising:

- a) a geometrically and magnetically axisymmetric plurality of rings surrounding the drill fluid carrying means wherein the plurality of rings further comprises: a central ring array, an upper ring located above the central ring array, and a lower ring located below the central ring array, each ring is axisymmetrically polarized and the direction of polarization for each ring differs progressively along the plurality of rings; and,

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20 ii) a means for producing an oscillating field in the formation.

9. The apparatus of claim 8, wherein a section of the carrying means is comprised of a magnetically permeable material.
10. The apparatus of claim 8 further comprising a deep, recessed area on the drilling means between an uppermost magnet of the upper array and a lowermost magnet of the lower array.
11. The apparatus of claim 8, wherein the central ring array comprises a plurality of inner rings wherein the polarization of each inner ring changes progressively such that an angle between the polarization and a transverse radius vector varies linearly for each inner ring.
12. The apparatus of claim 8 wherein the polarization direction of the upper ring is radially opposite to the polarization direction of the lower ring.
13. An apparatus for generating a magnetic field, comprising:
- a) a drilling means for drilling a borehole into the formation;
 - b) a means for carrying drilling fluid through the drilling means;
 - c) a measuring means, connected to the drilling means, for making nuclear magnetic resonance measurements while the borehole is being drilled, the measuring means comprising:
 - i) a means for producing a substantially axisymmetric static magnetic field through the drilling means and into the formation, the static magnetic field producing means comprising:
 - a) an axially magnetized upper magnet surrounding the carrying means; and,

b) an axially magnetized lower magnet surrounding the carrying means and axially separated from the upper magnet by a distance such that the contour lines generated by the static magnetic field are substantially straight in the axial direction at the depth of investigation where the nuclear magnetic resonance measurement is obtained; and,

ii) a means for producing an oscillating field in the formation.

14. The apparatus of claim 13 further comprising at least one magnetically permeable member for shaping the static magnetic field located within the drilling means between the lower magnet and the upper magnet.

15. The apparatus of claim 14 wherein at least one magnetically permeable member is comprised of a section of the drill fluid carrying means.

16. The apparatus of claim 14 wherein at least one magnetically permeable member is comprised of a chassis surrounding the drill fluid carrying means.

17. The apparatus of claim 15 wherein at least one magnetically permeable member is comprised of a chassis surrounding the section of the drill fluid carrying means.

18. The apparatus of claim 13 further comprising a region between the upper magnet and the lower magnet for locating electronics.

19. The apparatus of claim 13 wherein a static magnetic field having a low gradient is generated at the depth of investigation where the nuclear magnetic resonance measurement is obtained.

20. The apparatus of claim 13 wherein a static magnetic field having a high gradient is generated at the depth of investigation where the nuclear magnetic resonance measurement is obtained.

21. An apparatus for generating a magnetic field, comprising:

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a) a housing;

b) a measuring means, located inside the housing, for making nuclear magnetic resonance measurements, the measuring means comprising:

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i) a means for producing a substantially axisymmetric static magnetic field through the housing and into the formation such that the contour lines generated by the static magnetic field are substantially straight in the axial direction at the depth of investigation where the nuclear magnetic resonance measurement is obtained;

ii) a means for producing an oscillating field in the formation; and,

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c) at least one magnetically permeable member for shaping the static magnetic field.

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22. The apparatus of claim 21 wherein the means for producing the static magnetic field comprises a plurality of segments surrounding the permeable member, each segment is magnetized in a direction radially outward from and perpendicular to the longitudinal axis of the apparatus.

23. The apparatus of claim 21 wherein the means for producing the static magnetic field comprises a geometrically and magnetically axisymmetric plurality of rings surrounding the permeable member wherein the plurality of rings further

comprises: a central ring array, an upper ring located above the central ring array, and a lower ring located below the central ring array, each ring is axisymmetrically polarized and the direction of polarization for each ring differs progressively along the plurality of rings.

5 24. The apparatus of claim 21 wherein the means for producing the static magnetic field comprises:

- a) an axially magnetized upper magnet; and,
- b) an axially magnetized lower magnet axially separated from
the upper magnet by a distance such that the contour lines
10 generated by the static magnetic field are substantially
straight in the axial direction.

25. The apparatus of claim 24 wherein a static magnetic field having a low gradient is generated at the depth of investigation where the nuclear magnetic resonance measurement is obtained.

15 26. The apparatus of claim 24 wherein a static magnetic field having a high gradient is generated at the depth of investigation where the nuclear magnetic resonance measurement is obtained.

27. An apparatus for generating a magnetic field, comprising:

- a) a drilling means for drilling a borehole into the formation;
- 20 b) a means for carrying drilling fluid through the drilling means;
- c) a measuring means, connected to the drilling means, for making nuclear magnetic resonance measurements while the borehole is being drilled, the measuring means comprising:

i) means for producing a plurality of substantially axisymmetric static magnetic fields through the drilling means and into the formation at a plurality of regions of investigation where the nuclear magnetic resonance measurement is obtained, and such that the contour lines generated by at least one static magnetic field are substantially straight in the axial direction;

ii) means for producing an oscillating field in the formation; and,

d) at least one magnetically permeable member located inside the drilling means for shaping the static magnetic field.

10 28. The apparatus of claim 27 wherein the means for producing a plurality of substantially axisymmetric static magnetic fields further comprises means for producing a first static magnetic field which comprises an axially magnetized upper magnet surrounding the carrying means and an axially magnetized central magnet surrounding the carrying means and axially separated from the upper magnet by a first distance.

15 29. The apparatus of claim 28 wherein the means for producing a plurality of substantially axisymmetric static magnetic fields further comprises means for producing a second static magnetic field which comprises the axially magnetized central magnet surrounding the carrying means and an axially magnetized lower magnet surrounding the carrying means and axially separated from the central magnet by a second distance.

20 30. The apparatus of claim 29 wherein the means for producing the first static magnetic field generates a static magnetic field having a low gradient at a first

region of investigation where the nuclear magnetic resonance measurement is obtained.

31. The apparatus of claim 30 wherein the means for producing the second static magnetic field generates a static magnetic field having a low gradient at a second
5 region of investigation where the nuclear magnetic resonance measurement is obtained.

32. The apparatus of claim 30 wherein the means for producing the second static magnetic field generates a static magnetic field having a high gradient at a second
10 region of investigation where the nuclear magnetic resonance measurement is obtained.

33. The apparatus of claim 29 wherein the means for producing the first static magnetic field generates a static magnetic field having a high gradient at a first
region of investigation where the nuclear magnetic resonance measurement is obtained.

15 34. The apparatus of claim 33 wherein the means for producing the second static magnetic field generates a static magnetic field having a high gradient at a second region of investigation where the nuclear magnetic resonance measurement is obtained.

35. An apparatus for generating a magnetic field, comprising:

- 20 a) a housing;
- b) a measuring means, located inside the housing, for making nuclear magnetic resonance measurements, the measuring means comprising:

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- i) means for producing a plurality of substantially axisymmetric static magnetic fields through the housing and into the formation at a plurality of regions of investigation where the nuclear magnetic resonance measurement is obtained , and such that the contour lines generated by at least one static magnetic field are substantially straight in the axial direction;
 - ii) a means for producing an oscillating field in the formation; and,
 - c) at least one magnetically permeable member for shaping the static magnetic field.

10 36. The apparatus of claim 35 wherein the means for producing a plurality of substantially axisymmetric static magnetic fields further comprises means for producing a first static magnetic field which comprises an axially magnetized upper magnet surrounding the permeable member and an axially magnetized central magnet surrounding the permeable member and axially separated from the upper magnet by a first distance.

15 37. The apparatus of claim 36 wherein the means for producing a plurality of substantially axisymmetric static magnetic fields further comprises means for producing a second static magnetic field which comprises the axially magnetized central magnet surrounding the permeable member and an axially magnetized lower magnet surrounding the permeable member and axially separated from the central magnet by a second distance.

20 38. The apparatus of claim 37 wherein the means for producing the first static magnetic field generates a static magnetic field having a low gradient at a first

region of investigation where the nuclear magnetic resonance measurement is obtained.

39. The apparatus of claim 38 wherein the means for producing the second static magnetic field generates a static magnetic field having a low gradient at a second
5 region of investigation where the nuclear magnetic resonance measurement is obtained.

40. The apparatus of claim 38 wherein the means for producing the second static magnetic field generates a static magnetic field having a high gradient at a second
10 region of investigation where the nuclear magnetic resonance measurement is obtained.

41. The apparatus of claim 37 wherein the means for producing the first static magnetic field generates a static magnetic field having a high gradient at a first
region of investigation where the nuclear magnetic resonance measurement is obtained.

15 42. The apparatus of claim 41 wherein the means for producing the second static magnetic field generates a static magnetic field having a high gradient at a second region of investigation where the nuclear magnetic resonance measurement is obtained.

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